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THE EVIDENCE OF THE SENSES.

THE senses being the only avenues through which we derive our knowledge of the material world, we are prone to place implicit reliance on their indications, to overlook the part that reason and intelligence play in the interpretation that the mind puts upon the phenomena presented. Indeed, our intuitive interpretations of physical manifestations are generally mistaken for the indications of the senses themselves. Apart from experience, reason, and intelligence, it is very questionable whether the indications of the senses would convey to us any useful and substantial information. The organs of sense were never, in fact, designed by nature as instruments of scientific inquiry; they were never intended to give us direct and accurate information in relation to the physical qualities of matter. These gates of knowledge are always open; but we are not the passive recipients of knowledge. The fable of Proteus is a true picture of the combat between man, eager for knowledge, and the stubborn guardian charged with the preservation of the secrets of destiny. The sea-god changed himself into various shapes before speaking, and yielded only to the hero who, far from being moved by his transformations, bound him with bands of increasing pressure. Such is nature herself; her answers are always true; but, before allowing truth to shine forth, she arrays herself in the garments of error, or hides herself behind the phantoms of illusion, and will only assume her proper shape under the determined pressure of a resolute disciple of science.

When a question arises as to any matter of fact or appearance, what is more common than the observation, "Must I not believe the evidence of my senses?" And yet, no evidence is more misleading and fallacious, and there are no witnesses that require more careful scrutiny and more strict cross-examination than these very senses. It is true that in some particular applications of them we are compelled to take the testimony, as in our courts of justice, for what it appears to declare. But in any case of doubt, the senses are the most fallible guides that can be selected.

Notable illustrations are afforded by the indications of sight, the sense that is supposed to afford us the most precise and accurate knowledge. All are familiar with the phenomena that accompany the rising and setting of the sun and moon. The impression produced is that of an apparently large orb, vastly larger than when it is near the meridian. Yet nothing is more certain than that the real apparent magnitude of the sun and moon when near the horizon is not only not greater, but, if we adhere to the strict limits of truth, is in fact apparently less than when they are higher in the firmament.

Let any one adopt any convenient method of measuring the apparent magnitudes of the sun or moon in the horizon and on the meridian, and they will be found to be sensibly the same. This may be accomplished by extending two threads of fine silk parallel to each other in a frame; place them in such position, and at such a distance from the eye, that when presented to the sun or moon, in the horizon, they will exactly touch its upper and lower limbs. Let this arrangement be preserved until the sun or moon has risen to the meridian, and then let it be viewed in the same manner. It will be found that the threads will equally touch its upper and lower limbs, and their interval will still measure its apparent diameter. Astronomical telescopes are provided with a system of parallel wires, by which observations of this kind can be made with the greatest accuracy, and the application of this more refined method of measurement leads to the same conclusion.

We can scarcely call this an optical deception, for these very experiments prove that the eye is not deceived; the visual angle in both cases being precisely the same, the size of the image on the retina must have been the same. In fact, in the case of the moon, it is obvious that since she is nearly four thousand miles farther from us when she rises or sets than when she passes the meridian, her apparent diameter in the horizon, instead of appearing greater, ought to appear about a sixtieth part less than when on the meridian. This conclusion has been verified by refined methods of measurement.

Gassendi, a distinguished disciple of Galileo, thought that as the moon is less brilliant in the horizon than in the zenith, the pupil of the eye is opened wider in looking at it in the former station, and that it is for this reason that we see it larger. But for this conclusion to be valid, it would be necessary that variations in the openings of the pupil should produce variations in the dimensions of the image on the retina. This notion is wholly at variance with the principles of optics, which assure us that the size of the image produced in the eye is the same to whatever extent the pupil is dilated or contracted. The error is evidently one of the interpreting mind, and not of the sense of sight.

When objects are beyond a certain moderate distance from the eye, the size of the image on the retina has very little to do with our estimate of their apparent or real magnitude, unless we have reason to believe that the objects whose apparent dimensions are compared, are at the same distance from us. A child two feet high, at the distance of one hundred yards, presents the same apparent size to the organ of vision—subtends the same angle—as a man six feet high at the distance of three hundred yards. Yet no one would mistake the one for the other, however different their absolute distances. In all such cases our estimate of size is the result of a complex mental operation, in which allowance is made for the influence of distance. If circumstances are such that we can form no just estimate of distance, we are liable to be misled. In the case of terrestrial objects, our estimate of distance — and, of course, of size — depends in a great measure upon the number of intervening objects. The dilated size of the sun or moon when seen in the horizon is an illusion of the judgment, in which we estimate the distance of the orb to be much greater, because there are terrestrial objects interposed. Aloft we have no associations to guide us; its isolation in the expanse of the sky leads us rather to undervalue its apparent magnitude. Other considerations besides the interposition of objects enter into the complex mental operations on which our judgment of apparent size is founded; but all of them seem to be related to our estimate of distance. For example, a smoky condition of the atmosphere, by rendering the rising moon much less brilliant, enormously enlarges her apparent size; for, in this case, the obscuration of her brightness is associated with greater distance.

Again, the impression we obtain of the convexity or concavity of bodies is not the result of direct visual perception. There are optical instruments (pseudoscopes) in which objects that are really convex appear to be concave, and *vice versa.* Indeed, the art of painting is in great measure based upon the imperfection of the information conveyed through the medium of sight. This is particularly true of landscape painting. The luminous diverging lines occasionally seen in the air toward sunset, in a sky full of partially broken clouds, sometimes termed "the sun drawing water," are in reality parallel. They are, in fact, sunbeams through apertures in the clouds, partially intercepted and reflected by the dust and vapors suspended in the atmosphere. Sometimes they may be seen to diverge from a point near the western horizon, and to converge toward an opposite point in the east, in a manner analogous to the meridian lines on a terrestrial globe. This apparent deviation from parallelism is the result of the laws of perspective. A similar phenomenon, arising from the same cause, is sometimes presented by parallel bands of fleecy clouds.

In this view of the subject, we certainly cannot be said to see directly the position of a body by a simple effort of sight. By means of the eye we gather a variety of data, which are submitted to a rapid mental analysis. When the body is near, the differential qualities on which our judgment is based are substantial and obvious, so that he who runs may read. As the distance increases, the calculation grows nicer; only a careful scrutinizing eye will notice the delicate touches in outline, proportion, or shading, on which the problem hangs. At still greater distances, it is impossible for any eye or any mind to divine the true position and distance. When this limit is reached, our decision is held by so weak a tenure that the slightest adventitious circumstance, such as the intervention of objects or the greater or less brilliance of the bodies, determines our judgment.

There is another illusion belonging to sight, examples of which may be found in daily experience, which, nevertheless, I have not seen as minutely analyzed as might be desirable. I refer to the apparent motion of a body at rest, and the converse. In both cases the apparent motion is invariably in the opposite direction to the real motion. In the case of the rotation of the earth upon its axis from west to east, we imagine ourselves to be at rest, while the sun and other heavenly bodies appear to move from east to west. To the passengers on shipboard the shore appears to recede as the ship leaves the land. In like manner, to one riding rapidly along a road, the trees seem to move backward.

On the other hand, if we are in a railway car that is in a state of rest, the motion of a train on an adjacent track is transferred, in our conception (in an opposite direction), to the car in which we are seated; and if the passing train is long, the feeling of uncertainty becomes heightened, and sometimes almost painful. Similarly, if, while we are standing upon the edge of a wharf, a large ship gradually approaches us, as soon as she gets sufficiently near, the motion of the ship is apparently transferred to the wharf; and the impression is so powerful, that most uninitiated persons will absolutely stagger. In like manner, when the external covering of an observatory, consisting of the cylindrical sides and hemispherical dome, is made to revolve while we are within, the motion is almost invariably transferred to the platform upon which we are standing.

The following explanation, which was, I believe, first suggested by Professor Joseph Henry, in 1849, will be found to embrace all possible cases: By long experience, extending back to the period of early childhood, and possibly inherited from untold generations of progenitors, the mind has acquired the habit of inferring, without reflection, that when two bodies are relatively in motion, the motion belongs to the smaller, and that the larger is at rest. This inference is probably inseparably associated with the equally early experience, that it is more difficult to set a large body in motion than a small one. It is not necessary to the effect that one of the bodies should really be the larger, but that, at the time, it should occupy a larger portion of the field of view. Moreover, in order to secure the result, it is absolutely necessary that all concomitant circumstances, unconnected with apparent size, that influence our judgment of the direction of motion of bodies, should be removed. Thus, there must be no fixed objects intervening or visible beyond the body observed, as they might enable us to correct the impression. When these conditions are fulfilled, I believe it will be found to be a universal law that apparent size determines to which of the bodies the motion is referred, on the principle that the apparently smaller body seems to move.

In the apparent diurnal motion of the heavenly bodies from east to west, produced by our actual motion from west to east, the earth seems to us vastly larger than any body exterior to it, and when motion is observed, we insensibly transfer it to the apparently smaller bodies. It is in vain that reason and calculation combine to assure us that the sun is more than a million times the bulk of the earth; he occupies but a comparatively small portion of our field of view, and, in spite of the deductions of reason, he seems to us much smaller than the earth, and we transfer the motion to him. In like manner, in the apparent recession of the shore from an observer on shipboard, the objects on land occupy a much smaller portion of our field of view than the ship on which we are standing; and therefore, in accordance with the principle, our motion is transferred to them. The same is evidently true in relation to the apparent backward motion of the trees in riding along a road.

This principle is equally applicable to the opposite class of phenomena. Thus in the case of the train of cars: the train on the contiguous track is so near to us that all external fixed objects are excluded from our view; and as it occupies a larger portion of the field of view than the car in which we are seated, we imagine the latter to be in motion, because it is apparently the smaller body. The illusion is still more perfect in the case of the revolving dome of the observatory, because the moving body occupies the whole space around the observer.

The following remarkable phenomenon, in which the motion of the observer is not involved, admits of a similar explanation. When large and detached masses of clouds are rapidly passing between us and the moon, provided there are no intervening objects, it is very difficult to resist the impression that it is the moon that is moving. If the clouds are small, no such illusion is produced. It may be objected that, even in case the clouds are small, yet, as they are apparently larger than the moon, the latter ought to seem to move under all circumstances. The answer is, that when the clouds are small we are able to see the stars in the vicinity of the moon, and the apparent invariability of her distance from them enables us to correct the impression, as in the case of fixed intervening objects.

In all the instances heretofore enumerated, it appears that the sense of sight does not give us any positive and direct information; the eye only furnishes the data, from which experience, reason, and judgment rapidly draw the conclusions that are ordinarily ascribed to visual perceptions. But even in the case of colors, which are probably qualities conveyed to our minds directly through the medium of sight, the character of our perception depends, in many cases, upon the previous condition of the organ of vision, as well as many other adventitious circumstances that render the phenomena exceedingly complex and very difficult of interpretation. Thus, if we look steadily, for a considerable time, at a strongly illuminated red object on a black ground, the intensity of the color soon becomes enfeebled; if now the eyes are suddenly directed toward a white surface close beside it, we shall see a green image of the same shape and size as the object. In like manner, if the eye be directed intently upon the disk of the sun at rising or setting, when he is red, on closing the eyelids, a distinctly green image of the solar disk will be perceived. Indeed, when the object looked at is brilliantly illuminated, the accidental colors that manifest themselves on closing the eyes constitute a curious and perplexing succession of complementary color-tints, which will continue to be visible until the retina recovers its state of repose. These subjective sensations of color have been carefully investigated by Plateau, who thereby lost his sight in the cause of science.

Metaphysicians and physiologists have differed widely in relation to the services that ought to be attributed to the sense of touch. Some have greatly exaggerated them, considering it the sense *par excellence.* Anaxagoras ascribed the superiority of man over other animals, and his preëminence in the universe, to the hand. Aristotle and, after him, Galen, termed the human hand the "instrument of instruments." Later, Helvetius revived the idea, "that man is the wisest of animals because he possesses hands." The notion has been expanded by Condillac, Buffon, and many modern metaphysicians and physiologists. Buffon, in particular, assigned so much importance to the touch that he ascribed the superiority of the intelligence of one person over another to his having made a more prompt and repeated use of his hands from early infancy. He therefore recommended that infants should be encouraged to use them freely from the moment of birth. Others have considered the hand the source of our mechanical capabilities. The same answer applies to all these views. The hand can only be regarded as an instrument by which information of particular kinds is conveyed to the mind, and by which other functions are executed, under the guidance of an intelligent will. The idiot frequently has the sense of touch more delicate than the man of genius, or than the most skillful mechanician; whilst the most ingenious artists have by no means the highest development of the tactile sense.

But it has been asserted that the touch is, of all the senses, the least subject to error, and that it is, therefore, the correcting, the regulating, the geometrical sense. In part only is this substantiated by observation and experience. It will be shown in the sequel that some of the errors of this sense are as striking and grievous as those that happen to the other senses. The sensory apparatus constituting touch is far less specialized than the other organs of sense. As far as known, the same tactile nerves are cognizant of several distinct kinds of sensation. For example, the organ of touch recognizes pain, temperature, titillation, and, with the help of muscular action and motion, size, shape, roughness, and various physical qualities of special materials and objects. On the other hand, the organs of special sensation, such as those of smell, taste, hearing, and sight, receive impressions of a particular kind, in consequence of the peculiar character of the nerves with which they are supplied.

Some physiologists have imagined that the sense of temperature is received through some other channel than the sensory apparatus contained in the integuments; but the most trustworthy experiments afford no adequate ground for the supposition. At present these researches seem to indicate that the several characteristic sensations of touch—pain, heat and cold, and titillation—all arise from affections of the tactile nerves of common sensibility, which are distributed in different portions of the skin. Hence we may infer that the difference of these sensations is to be ascribed to the peculiarity of the impressions received at the peripheral extremities of the tactile nerves. One of the great purposes of the sense of touch is to enable us to judge of the temperature of bodies; and this office it executes alone. It requires no previous exercise; yet how inaccurate, how fallacious, is its appreciation of temperature. This sense is called into action only where there is difference between the temperature of the sensory organ and that of the surrounding medium, or of the substances with which it is specially brought in contact. The intensity of the impression is determined rather by the relative than by the absolute thermal condition of the body that excites it. Thus, if one hand be immersed for a time in hot water, and the other in ice-cold water, and then both be plunged into tepid water, this will seem cool to the former, and warm to the latter. A person coming out of cold air into an atmosphere of moderate temperature derives from it a feeling of genial warmth; whilst another coming into the same atmosphere from one much hotter complains of its chilliness. So much are our sensations in this respect dependent on the temperature that has previously existed that the comfortable point will be found to vary at different seasons.

During the Arctic voyages made by Parry, Franklin, Ross, Kane, Nares, and others, it was found that a zero temperature seemed quite mild after the thermometer had been twenty or thirty degrees below that point. In like manner, if on a hot summer day we descend into a deep cave, it will feel cold; if we descend into the same cave on a frosty day in winter, it will feel warm; yet a thermometer will prove that it has nearly the same temperature in both seasons.

But even when the state of our body is the same, the sense of feeling will be found equally fallacious as regards the temperature of bodies. When the temperatures of different substances are compared by the hand, the sensation experienced is not so much influenced by the absolute amount of free heat possessed by each, as by its relative power of abstracting or imparting heat to the skin. When bodies are colder than the hand, substances that are good conductors are felt to be colder than those which conduct heat badly, although really of the same temperature, because they abstract heat from the sensory surface more rapidly. On the contrary, if the bodies are warmer than the hand, the best conductors will seem to be the hottest, because their heat is most readily imparted. For a like reason, if we plunge into water that is of the same temperature as the surrounding atmosphere (provided it is below the natural temperature of the body), the liquid will seem to be cold.

Moreover, the sense of temperature is influenced in a remarkable degree by the extent of surface on which the impression is made. Every one is familiar with the fact that hot water in which a single finger may be held without inconvenience, will be felt to be intolerable when the whole hand is immersed in it. It has been shown by Professor E. H. Weber that if one vessel of water be heated to ninety-eight degrees (F.), and another to one hundred and four degrees (F.), and the whole hand be immersed in the former, while the finger alone is immersed in the latter, a wrong judgment of their relative temperatures will probably be given.

The interpretation that the mind puts upon the impressions made by external objects upon the tactile organs, is partly the result of intuition and partly of experience. Thus, in cases of amputation, an impression made upon the divided extremities of the nervous trunks is intuitively referred to the parts to which they were originally distributed. In like manner, when our tactile organs are in an unaccustomed position, we still interpret impressions made upon them as if they were in their ordinary relations to each other. For example, in the experiment, mentioned by Aristotle, of rolling a pea between two fingers of one hand, which are crossed instead of being parallel, so that the surfaces usually most distant are brought into proximity with each other, the sensation is that of a separate convex body opposed to each of these surfaces, so that the single body seems to be double. When the eyes are closed, we are completely misled by the fallacious interpretation of the impression produced by the lateral portions of the fingers being brought in opposition, which are naturally in a different situation, and at a distance from each other. There are many similar deceptions. If a book is held between the hands, the palms turned outward, the arms being previously crossed, the edge of the book appears in this case to be bent at an angle. If one hand is passed over its corresponding shoulder, and the other under the arm belonging to it, and a book held between the hands thus placed, the edges of the leaves of the book appear to the one hand to be a continuation of the surface of the back of the book. If the tongue is folded back upon itself, the portion thus placed appears to be a foreign body laid upon the tongue, except that the sensibility of the part thus turned is still perceptible. If the tongue is turned edgewise, and then placed against the teeth, the teeth appear to be inclined instead of vertical.

In a large proportion of other cases, our interpretation of tactile sensations—especially of all those relating to the configuration, density, etc., of external objects—is based upon experience. Those who have watched the eagerness with which the infant examines by touch every attractive object within its reach are at no loss to perceive how the experience thus early interwoven with the mind, in combination with that derived through the visual sense, causes the tactile and visual perceptions to be so indissolubly associated that each is continually suggesting the other. From observations made upon persons born blind, when the visual power has been first obtained it is certain that the notions of form previously acquired by touch do not aid in the visual discrimination or recognition of objects. For example, if any such person had learned to distinguish a sphere, a cube, and a pyramid by the touch, he would not be able to say which was which by looking at them, until he had learned by experience to associate the two classes of perceptions. In such cases, when the sight is first restored, no ideas are formed of distance, size, or solidity. The blind man of Bethsaida, when his sight was restored, said, "I see men as trees walking." The fourteen-year-old lad who was "couched" by Cheselden, when he first saw, thought all external objects touched his eyes. An amusing anecdote recorded of him shows the complete want, at least in man, of any natural or intuitive connection between the ideas formed through visual and through tactile sensations. He was well acquainted with a dog and a cat by feeling, but could not recognize their respective characters when he saw them; and one day he took up the cat and felt her attentively, and then setting her down, said, "So, puss, I shall know you another time."

It is scarcely necessary for me to dwell on the fallacies of hearing, taste, and smell, as no one is disposed to ascribe an undue degree of infallibility to the impressions furnished through these senses. As regards hearing, the inaccuracies of its indications in relation to the distance, direction, and character of sounds, are proverbial. Indeed, the art of ventriloquism rests upon the uncertainties and inaccuracies of information derived through the organ of hearing. By skillful modifications of the intensity and the qualities of sounds, and by adroitly directing the attention of the hearers to the proper quarters, it is easy for the operator to produce the most complete acoustic illusions.

Certain external agencies are known to excite impressions through several different sensory channels; the sensation being, however, in each case characteristic of the particular nervous apparatus. The ear is unable to distinguish the slightest difference between luminous and dark objects; neither is the eye able to discriminate between acute and grave sounds; nor can the taste appreciate the most strongly odoriferous bodies. Hence, we may infer that no nerve of special sensation can, by any possibility, assume the function of another.

From a careful consideration of all the facts connected with the exercise of the senses, it must be evident to every reflecting mind that the organs of sense were not designed to supply us with philosophical instruments. The eye, the ear, and the touch, though admirably adapted to serve our purposes, are not severally a microscope or telescope, a sonometer or siren, and a thermometer or pyrometer. It was well observed by Locke that an eye adapted to discover the intimate constitution of the atoms forming the hands of a clock, might be, from the very nature of the mechanism, incapable of informing us of the hour indicated by the same hand. A telescopic eye that would enable us to see the details of structure on the surface of Jupiter or Saturn, would ill requite its owner for that ruder power which guides him through the town he inhabits and enables him to recognize the friends who surround him. We are not the passive recipients of knowledge. There must be an external world of light and of sound, to give impressions to the eye and to the ear; there must also be an active, intelligent mind by which they are molded, combined, and interpreted, so as to constitute substantial knowledge. It is as necessary that thought should be exerted as it is that there should be something upon which it is exerted. Sensation is passive; attention is active. The distinction is manifest by its own nature; and we find evidence of it in the very forms of language. To look is more than to see; to listen or hearken is more than to hear; to feel is more than to touch.

JOHN LECONTE.